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Approved For Public Release; Distribution Is Unlimited

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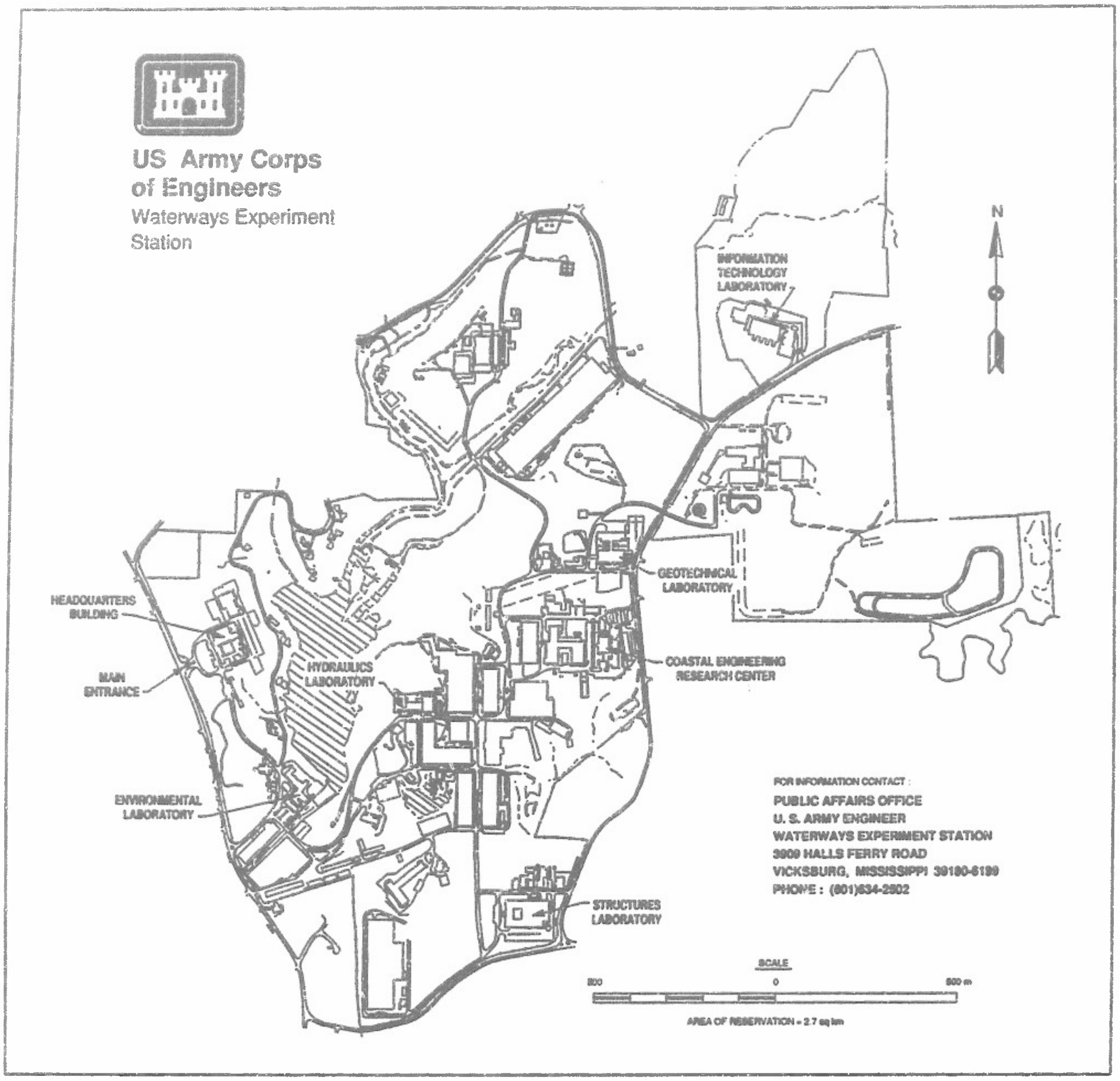

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PREFACE

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This research effort was under the overall direction of Messrs. C. R. Welch, and H. G. White, EED. Mr. L. K. Davis was Chief, EED, and Mr. B. Mather was Director, SL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Leonard G. Hassell, EN.

CONTENTS

Introduction

HULL is a complex and versatile hydrodynamic computer code. The original version was developed at the Air Force Weapons Laboratory in 1976 [1]. It has the capability to run Eulerian or Lagrangian modes of calculations and has a wide range of options representing material selection and various physical behavior. One of the drawbacks of HULL is its explicit mode of calculation with a severe time-step limitation. The time-step of calculation, restricted by the Courant, Friedricks and Lewy (CFL) condition, often hampers its efficiency in solving large multidimensional problems. Mere size and complexity of the code adds a certain amount of rigidity in upgrading HULL. It would be ideal if calculations of interest to the Army could be speeded up substantially.

A prior report [2] by the author noted certain anomalies along the centerline of HULL axisymmetric calculations. In the previous study, airblast velocity profiles, pressure plots, and the time of arrival at ground zero, were computed from an airburst detonation. The need for a quicker solution in such an airblast calculation was apparent. The present effort concentrates on upgrading HULL by adding a one-dimensional spherical airblast code, SAP (Spherical Air Puff).

The original SAP code was developed at the Air Force Weapons Laboratory in the 1960's [3]. However, the version [4] which was used in this study was developed by the S-Cubed Corporation in the mid 1980's. It has a stand-alone capability of airblast calculations. SAP can also prepare station plots or feed in inputs to HULL or SHARC calculations. Unfortunately, the version that was available to the author lacked several subroutines. The need for complete documentation resulted in redefining several system parameters and options. The program was added to the HULL library in UNICOS and VAX modes. However, thorough testing of SAP against measured airblasts still needs to occur.

This report presents the discussion of the parameters and options in the newly added capability. For brevity, only the important details will be presented here. The executable versions and procedures are given in program listings in the appendix.

HULL SYSTEM

Before the discussion of SAP begins, it is important to recognize and understand the HULL framework. The HULL system consists of several programs which furnish pre- and post-processing needs in addition to the HULL program, which performs the hydrodynamic calculations. The programs share a common library of utility routines. HULL is very flexible in being able to run on several computer systems and can be upgraded very easily because of its modular structure. HULL is prepared by a proprietary program called SAIL, developed by Shalimar Research, Inc [5]. This code guides the flow of instructions in the HULL system by using statements, called SAIL directives, which prepare or change the compilable HULL. This is important to recognize because the SAP code which was added to the HULL system would not function itself without being processed by SAIL.

The details of the SAIL program cannot be published because of the proprietary guidelines. It operates under three major modes - executive/maintenance, update/generate and copy/convert. The SAIL maintenance and executive directives are its normal mode of operation. However, they cannot be processed simultaneously with the update/generate mode. Once a program is transported between systems using the copy/convert mode, it can be added or upgraded for another installation using proper SAIL directives. Finally, once system parameters and options are defined and available, a program can be executed in the normal mode.

The normal mode of execution is prepared for HULL with the pre-processing programs PLANK and KEEL. The preparation of the compilable HULL is achieved by PLANK, which defines the options block. KEEL utilizes the material library and generates the input/restart tape for hydrodynamic calculations of HULL. Finally, there are post-processing programs such as PULL and STATion to plot the results of hydrodynamic calculations and analyze data.

SAP Code

SAP is similar to the program HULL. It already contains post-processing programs such as SAPPLT and STAPLT. It was therefore unnecessary to share those programs from the HULL system. Further, SAP does not need the HULL material library "MATLIB", since materials are furnished in several subprograms within SAP which can be compiled upon need. Currently SAP has 24 materials in its library (these include burned and unburned materials). They are - AIR, TNT, BTNT, PBX, BPBX, PENT, BPENT, ANFO, BANFO, METH, BMETH, WATER, HMX, BHMX, COMB, BCOMB, FOAM, CFOUR, BCFOUR, PETN, BPETN, IRMT, BIRMT and PLUG. The material names beginning with the letter "B" represent burned explosives. A continuous burn routine, based upon the Chapman Jouget Theory, is available in SAP.

SAP also has the capability of using six different ambient models. They are: Tropical, Temperate, Arctic, Exponential, Constant Energy and Hiroshima. SAP calculations can incorporate radiation loss. There are three radiation loss schemes - one based upon SPUTTER calculations, one using emissivity data by Gilmer [3], and a radiation-diffusion package with free streaming at the edge of the temperature gradient. SAP uses a real atmosphere that is stable under an r^{-2} gravity field, and an equation of state for air that is an empirical fit to Hilsenrath's data [6].

SAP can be run with a cartesian, cylindrical or spherical system of coordinates. It has two differencing schemes. The original scheme is

Lagrangian, whereas the second scheme, which is also utilized in the HULL code, and can be run as Eulerian or Lagrangian, as set by an option. SAP can incorporate artificial viscosity in linear or quadratic form. It even has a routine for an artificial compression method. The SAP plot routines can furnish overpressures, overdensity, and velocity vectors versus radius. SAP was originally developed for a CDC or CRAY machine under the CTSS mode. Therefore to run under CRAY-UNICOS at WES, some parameters needed to be altered and some new ones introduced that would be suitable to the system.

SAP Options

SAP has more than 50 options which need to be defined to prepare a compilable version. If one prepared a PLANK version of SAP, that program could define the options in the pre-processing run. The main SAP run can use those defaults, or modify some dynamic options during the executable processing. Such a program was prepared by the author and currently resides in the SAP directory under the name SPLANK. However, unlike HULL, fewer options in SAP require dynamic alteration. Therefore one could skip the use of SPLANK and directly introduce the options during the update/generate mode of SAIL.

Some options also have dependency on other options. Therefore care must be exercised in altering them. Appendix A shows a list of default and redefined options as listed by SAIL during pre-processing of SAP. SAP was added to the HULL system as the procedure RUNSAP. Some of the printed options in the list therefore come from the HULL options and the system parameters. Appendix B, which was reproduced from [4], gives a list of SAP options and overviews of the subroutines in SAP. One must keep the default options in mind while upgrading the SAP system. The defaults need not be altered at all if the physical problem does not require it. In the present CRAY version of SAP, the user needs to choose the following options:

1) SAPNM - represents the number of materials in the problem.
2) SAPMX - represents the maximum grid size.
3) SPGEOM - chooses the type of geometry in the run.
   (Cartesian - 1, Cylindrical - 2 and Spherical -3)
4) SPMTHD - chooses between differencing techniques in the solution process.
5) NMAT - represents the number of material boundaries in the problem. Note that this number may be larger than SAPNM, depending on the arrangement of materials.
6) RESTART & HYDRA - These are similar options. The latter should be chosen to generate a restart file, whereas the former should be chosen when a restart file already exists.
7) BURN = 1 must be used if explosives are present in the problem. In those cases, the explosives can have both burned and unburned choices (material name preceded by "B").
8) Other important options include RAD, VISC, ACM and FCT to specify physical and computational choices, whereas SPUTIN, HCUTIN and PLOTIT give pre- and post-processing choices.

SAP INPUT

After the pre-processing SAIL run produces a compilable SAP, it must be compiled, linked and executed with a proper SAP input. See the example in Appendix C. SAP inputs have generally three sections.

The first section starts with the keyword "sap". This section enters the problem number and starting requests in terms of time and cycles. The problem number and starting information must be carefully inputted on a restart run, the failure of which will immediately abort the run.

The second section starts with the keyword "input". This section has the stopping request, the header block definition and definitions of the "z-block" parameters. These parameters are upgraded at each run and therefore some of these can be considered as dynamic options. A complete list of the z-block parameters are available in appendix D.

The last section starts with the keyword "region". This is similar to the keyword "mesh" in KEEL runs. It has six different variables separated by the word CELLS. These variables are - material name, dx, energy, rho, speed, and bound. Material names have to be used exactly as they were introduced in the SAIL pre-processing. DX represents the width of cells in this part of the mesh.

Energy and rho represent the energy and mass densities. All units are expressed in the CGS (Centimeters, Grams, Seconds) unit system. Speed represents the speed of the material in this part of the mesh. Again, this quantity is expected to be a variable. The first cell must be assigned some initial velocity. A zero velocity input for the first cell will result in aborting the program. Bound represents the maximum number of cells for which the previous five variables hold. The default on bound is IMAX, the maximum number of cells in the problem. If there are several materials present in the problem, the bound values should be inputted carefully.

All of the above six variables may not be specified in a given problem. For example, the sample input in Appendix C has three materials - BPENT, PENT and AIR. The problem stacks up BPENT in the first cell, PENT in Cell 2 through 77 and AIR for Cells 78 through 100. The mesh size is a variable. As may be noticed from this example, only 4 variables (out of 6) were defined in the first three cells, 3 were defined between Cells 4 through 77 and only two were defined for the rest of the mesh. Further descriptions of input variables are presented in Appendix D.

The final word in the sap input is "end". Once these inputs are correctly specified, SAP outputs a "sap.out" and a "tape 4" (if option hydra is chosen).

Results

Appendix E shows the sequence of the batch run "jobsap.com". This batch job prepares the compilable version from the card input [4], compiles, links, and executes the program with the SAP input shown in Appendix C. The output "sap.out" is presented in Appendix F. It can be seen from the output that the program generates the z-block and the mesh configuration correctly.

This particular run has a problem in the subroutine "BURN", as reflected in the output. This code, like any other newly developed capability, has to be tested in various physical problems before confident statements can be made regarding its advantages and drawbacks. The error source is probably among input or material properties data or methodology of calculations. Further testings are currently in progress.

Conclusions and Recommendations

The SAP code was added to the HULL library of programs at WES. This code will provide an input for the HULL calculations, or it can produce one-dimensional solutions for airblast problems independently. The code remains to be tested in various physical problems.

One very useful application of the code will be to use it in the airblast calculations presented in [2]. It would be interesting to know whether SAP outputs can be inputted into HULL calculations with significant improvement in the overall run time of the HULL calculations. Another interest would be to see if the HULL input thus generated by the "firein" option in KEEL would produce a better arrival time of the shock at ground zero in the HULL run than was obtained previously.

SAP can also be used in the reverse mode, where HULL outputs are used as input to SAP by the program HULLCUT, which takes a slice of the multidimensional output. Finally, the newly-added capability of one-dimensional calculations can produce approximate and quick answers to significantly large problems as a stand-alone capability, where an early prediction can influence later decision making.

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Appendix A

```
1     sail library for version      124          of system hull
generated   3aug92


0     this library contains   140358 lines
0     generating source from programs on    3aug92
0      program        origin                   program        origin
          program        origin

0     *sap          210000
0     programs which are marked with an * will generate source in
this run
1     options defined at the beginning of this run

0     inst      =      16  mach      =      1  sail      =      0
0     runsap    =       1  tekcolor  =      0  eos       =      0
0     matlib    =       0  plank     =      0  common    =      0
0     proc-msc  =       0  hull      =      0  plotters  =      0
0     pull      =       0  station   =      0  plotvg    =      0
0     keel      =       0  lrez      =      0  sap       =      2
0     staplt    =       0  hullcut   =      0  sapplt    =      0
0     library   =       0  control   =      0
1options defined/redefined during executive processing
 cray      =      1
 opsys     =      2
 vendor    =      1
 pf        =      1
 objlib    =      0
 tapelib   =      3
 plotpkg   =      0
 remark    =      0
 mf        =      0
 cdc       =      0
 ibm       =      0
 cray      =      1
 vax       =      0
 sel       =      0
 vsos      =      0
 colour    =      0
 word      =     64
 byte      =      8
 date      =      2
 buffer    =      1
 sensesw   =      1
 nw        =      1
 cw        =      8
 cardl     =     10
```

cardo	=	8
double	=	0
exbl	=	0
debugl	=	0
debugs	=	0
mach	=	1
cdc	=	0
univac	=	0
vax	=	0
cel	=	0
ridge	=	0
spsvth	=	0
sapmx	=	100
spgeom	=	3
spmthd	=	1
sapnm	=	3
single	=	0
airopt	=	1
atmos	=	2
compare	=	0
nstat	=	0
nmat	=	3
matt	=	24
air	=	3
tnt	=	0
btnt	=	0
pbx	=	0
bpbx	=	0
pent	=	2
bpent	=	1
anfo	=	0
banfo	=	0
meth	=	0
bmeth	=	0
water	=	0
hmx	=	0
bhmx	=	0
comb	=	0
bcomb	=	0
foam	=	0
cfour	=	0
bcfour	=	0
petn	=	0
bpetn	=	0
irmt	=	0
birmt	=	0
plug	=	0
rezone	=	1
method	=	1
lbnd	=	0
rbnd	=	0
imax	=	100

```
 restart   =      0
 ktstd     =      0
 weight    =      1
 ngroup    =      0
 sputin    =      0
 hcutin    =      0
 hydra     =      1
 acm       =      0
 burn      =      1
 fct       =      0
 rad       =      0
 nm        =      3
 plotit    =      0
 geom      =      3
 visc      =      1
 euler     =      0
 jwl       =      1
 cray      =      1
 unicos    =      1
 eos       =      1
 sum       =      1
 route     =      0
 sys       =      2
 nchpwd    =      8
 nodpwd    =     22
 nbitpc    =      8
 nchar     =     16
 lev       =      1
 vector    =      0
 asciim    =      1
 disspl    =      0
 scaler    =      1
 nvarpr    =    500
 nh        =      5
 nbitpw    =     64
 nshift    =     32
 nshifl    =     56
 nchmtn    =      2
 nwpcv     =      2
 nzblk     =    100
 indxz     =    200
 nzblk2    =    200
 idim      =    300
 ijump     =    101
 ijptwo    =    201
0    2856 cards generated
1
0         end of normal   sail run
          system hull     version      124
```

Appendix B

```
*p        options
      20feb87
=
      20feb87
=        option   default          definition
      20feb87
=
      20feb87
=        atmos       2      atmosphere type
      20feb87
=                           =1   tropical atmosphere
      20feb87
=                           =2   temperate atmosphere
      20feb87
=                           =3   arctic atmosphere
      20feb87
=                           =4   exponential atmosphere
      20feb87
=                           =5   constant energy and pressure
      20feb87
=                           =6   hiroshima atmosphere
      20feb87
=        airopt      1      air type, this option is for use in
      20feb87
=                           conjunction with vector=1, cray=1
      20feb87
=                           =1   doan-nickel equation of state
      20feb87
=                           =2   gamma law equation of state
      20feb87
=                           =3   simple gamma law equation of state
      20feb87
=                           =10 four point interpolation
      20feb87
=         vector      0      vectorized eularian differencing, to be
used    20feb87
=                           only with cray=1
      20feb87
=                           =0   no vectorization
      20feb87
=                           =1   use vector routines
      20feb87
=        cray        0      sap run to be run on cray-1 computer
      20feb87
=                           =0   not a cray run
      20feb87
=                           =1   cray run
      20feb87
```

```
=        cdc        1     sap run to be run of cdc computer
     20feb87
=                         =0  not a cdc sap run
     20feb87
=                         =1  cdc sap run
     20feb87
=       restart     0     this option to restart a previous run
     20feb87
=                         =0  not a restart run
     20feb87
=                         =1  problem is a restart run
     20feb87
=       euler       0     reference frame option
     20feb87
=                         =0  lagrangian
     20feb87
=                         =1  eulerian ( use only with method 2
     20feb87
=                             single-material runs.)
     20feb87
=       geom        3     geometry option
     20feb87
=                         =1  cartesian
     20feb87
=                         =2  cylindrical
     20feb87
=                         =3  spherical
     20feb87
=           ktstd       0      1 kiloton standard left bdry input
condition    20feb87
=                         =0  not included
     20feb87
=                         =1  included.  method 2 should be used.
     20feb87
=                         subroutines as contained on sail file
     20feb87
=                         "dytaid" under the name 1ktstd should be
     20feb87
=                         loaded with sap if this option is used.
     20feb87
=                          options lbnd and/or rbnd must be set if
this    20feb87
=                         is to be used.
     20feb87
=       lbnd        0     left boundary condition option
     20feb87
=                         =0  no left boundary input
     20feb87
=                           =1  there is a left boundary condition
imposed. 20feb87
=                           if ktstd=0, a left boundary subroutine
called   20feb87
```

```
=
(method 1)  20feb87
=
(method 2)  20feb87
=
as    20feb87
=
method 1)  20feb87
=
      20feb87
=
must   20feb87
=
      20feb87
=
      20feb87
=         rbnd       0
only) 20feb87
=
    20feb87
=
      20feb87
=
    20feb87
=
permitted   20feb87
=
the    20feb87
=
    20feb87
=
      20feb87
=
imposed 20feb87
=
called  20feb87
=
(method 2)  20feb87
=
as     20feb87
=
      20feb87
=          method     2
      20feb87
=
      20feb87
=
      20feb87
=          weight     1
      20feb87
=
      20feb87
```

"lbound(time,distance,u,rho,i)"

"lbound(time,u,rho,i)"

which specifies speed, density and energy

a function of time (and distance, if

must be loaded.

also, the parameter "lbref" set by input

be zero, indicating a transmissive left

boundary

right boundary condition option (method 2

=0 right boundary condition is defined by

the option 'rezone'

=1 the right boundary is reflective. the

sap variable 'shkcel' will never be

to have values greater than imax - 2, and

calculation will not terminate when shkcel

reaches a value of imax - 2.

=2 there is a right boundary condition

if ktstd=0, a right boundary subroutine

"rbound(time,u,rho,i)"

which specifies speed, density and energy

a function of time must be loaded.

differencing scheme option

=1 old sap differencing

=2 hull differencing

weight option for method 2

=1 conventional hull boundary algorithm

```
=                                    ( bv=(v1+v2)/2 )
      20feb87
=                                =2  mass weighting boundary algorithm
      20feb87
=
      20feb87
=        nstat     0       number of stations in problem
      20feb87
=        nmat      1       number of material boundaries in
      20feb87
=                          problem at any given time (see below).
      20feb87
=        rezone    1       rezone option
      20feb87
=                        =0  no rezone (stop at right edge of mesh)
    20feb87
=                            =1  rezone (expand front fourth of mesh
while   20feb87
=                                conserving mass, momentum and total
energy) 20feb87
=                            =2  rezone (expand front fourth of mesh
while   20feb87
=                              conserving mass, momentum and
      20feb87
=                              mass*pressure)
      20feb87
=        nvarpr    400     maximum number of hydro variables per
      20feb87
=                          tape4 hydro record
      20feb87
=                          =imax*5 for method 1
      20feb87
=                          =imax*4 for method 2
      20feb87
=        imax      100     number of cells in problem
      20feb87
=        rad       0       radiation option
      20feb87
=                          =0  no radiation loss
      20feb87
=                              =1  prescribed power out based upon
sputter     20feb87
=                              calculations
      20feb87
=                          =2  emissivity based upon data by gilmer
      20feb87
=                                     =3  radiation diffusion with
free-streaming at  20feb87
=                             the edge of the temperature gradient.
     20feb87
=                          =4  -hfb must be set if rad=4- radiative
      20feb87
```

= heating using rate dependant thermal
20feb87
= layer model. currently used only when
20feb87
= angle=90.
20feb87
= ngroup 1 number of frequency groups in problem
(used 20feb87
= only when rad=3).
20feb87
= sputin 0 sputter input for mesh
20feb87
= =0 input is by means other than a sputter
tape 20feb87
= =1 input to fill mesh is from a sputter
tape 20feb87
= this option can be used at any angle with
20feb87
= any geometry.
20feb87
=
20feb87
= hcutin 0 input is from a tape4 generated by program
20feb87
= hullcut.
20feb87
= =0 input is by means other than hullcut.
20feb87
= =1 input is for fill the mesh form a
tape4 20feb87
= generated by hullcut. the tape4
contains 20feb87
= a z-block, a 'x' coordinate record,
and 20feb87
= the hydro data. the tape is used as
if 20feb87
= it were a restart tape. the option
can 20feb87
= used at any angle with any geometry.
20feb87
=
20feb87
= plotit 0 plot option
20feb87
= =0 no plot file is generated
20feb87
= =1 tape1 metafile is generated to plot
over- 20feb87
= pressure, overdensity and velocity as
a 20feb87
= function of time.
20feb87

```
=         hydra     1      restart option
       20feb87
=                          =0  no tape 4 is used, i.e., no restart
       20feb87
=                              capability
       20feb87
=                          =1  a tape4 (restart tape) is written
       20feb87
=         visc      1      artificial viscosity option
       20feb87
=                          =0  no artificial visc terms added
       20feb87
=                          =1  constant term added
       20feb87
=                          =2  variable term added
       20feb87
=         acm       0      artificial compression method option
       20feb87
=                          =0  no artificial compression used.
       20feb87
=                            =1  artificial compression applied to
mass,     20feb87
=                                  momentum and total energy in
compression    20feb87
=                              regions.
       20feb87
=         fct       0      flux corrected transport scheme
       20feb87
=
       20feb87
=         burn      0      high explosive material option
       20feb87
=                           =0  no material is present (isothermal
sphere)  20feb87
=                          =1  explosive material is present
       20feb87
=         nm        1      number of materials in the problem
       20feb87
=         matt      24     number of materials available in sap
       20feb87
=         air       1      =positive value if present in problem
       20feb87
=         tnt       0      =positive value if present in problem
       20feb87
=         btnt      0      =positive value if present in problem
       20feb87
=         pbx       0      =positive value if present in problem
       20feb87
=         bpbx      0      =positive value if present in problem
       20feb87
=         pent      0      =positive value if present in problem
       20feb87
```

```
=         bpent      0     =positive value if present in problem
     20feb87
=         meth       0     =positive value if present in problem
     20feb87
=         bmeth      0     =positive value if present in problem
     20feb87
=         anfo       0     =positive value if present in problem
     20feb87
=         banfo      0     =positive value if present in problem
     20feb87
=         water      0     =positive value if present in problem.
     20feb87
=                                (refer to subroutine waters for
instructions)   20feb87
=         hmx        0     =positive value if present in problem
     20feb87
=         bhmx       0     =positive value if present in problem
     20feb87
=         comb       0     =positive value if present in problem
     20feb87
=         bcomb      0     =positive value if present in problem
     20feb87
=         foam       0     =positive value if present in problem
     20feb87
=         cfour      0     =positive value if present in problem
     20feb87
=         bcfour     0     =positive value if present in problem
     20feb87
=         petn       0     =positive value if present in problem
     20feb87
=         bpetn      0     =positive value if present in problem
     20feb87
=         irmt       0     =positive value if present in problem
     20feb87
=         birmt      0     =positive value if present in problem
     20feb87
=         plug       0     =positive value if present in problem
     20feb87
=
     20feb87
=         the integers from 1 to nm should be assigned to
     20feb87
=         materials in the problem.  all other materials should
     20feb87
=         be set to zero.
     20feb87
=
     20feb87
=         a)   air(isothermal sphere)
     20feb87
=         b)   bpent,air
     20feb87
```

```
=        c)   bpent,pent,air
       20feb87
=        d)   water,bpent,pent,water
       20feb87
=        e)   bpent,pent,tnt,pent,air
       20feb87
=
       20feb87
=        should have the following options set as shown-
       20feb87
=
       20feb87
=             nm    nmat matt burn  (material codes)
       20feb87
=
       20feb87
=        a)   1      1     12    0     air=1
       20feb87
=        b)   2      2     12    0     air=2,bpent=1
       20feb87
=        c)   3      3     12    1     bpent=1,pent=2,air=3
       20feb87
=        d)   3      4     12    1     water=1,bpent=2,pent=3
       20feb87
=        e)   4      5     12    1     bpent=1,pent=2,tnt=3,air=4
       20feb87
=
       20feb87
=        except for a) (obviously) the ordering of the
       20feb87
=        material code numbers is arbitrary  (the fifth column
       20feb87
=        of the above example is not unique). note that the
       20feb87
=        last zone in the mesh must be included as a material
       20feb87
=        boundary.
       20feb87
=
       20feb87
=        sap consists of a fair number of subroutines linked by
       20feb87
=        blank and labeled common.  in addition to the summary
       20feb87
=        given below, most of the subroutines contain further
       20feb87
=        explanation of their functions.  for a detailed
       20feb87
=        description of card input to sap, see subroutine in.
       20feb87
=        the section labeled "constant" in sap outlines the
       20feb87
```

```
=       procedure for adding new materials to sap.
     20feb87
=
     20feb87
=
     20feb87
=       initializing routines - these are called when setting up
     20feb87
=       or restarting a sap problem.  they are not contained
     20feb87
=      within the main sap loop.  an asterisk before the routine
   20feb87
=      indicates that the routine is included only if the option
in   20feb87
=       parentheses after the description is true.
     20feb87
=
     20feb87
=       in-in2     card input to sap (see in for explanation of
     20feb87
=                  input format)
     20feb87
=     *restart     tape input (tape4,tape9)  restart
     20feb87
=                  if applicable (hydra)
     20feb87
=       cell       sets up mesh using input
     20feb87
=      set       defines zblk default values before input is read
  20feb87
=       rstzbk     places input that is read into the zblk (from
     20feb87
=                  tape or card input) into appropriate problem
     20feb87
=                  parameters
     20feb87
=       out        prints the initial zblk and the problem
     20feb87
=                  configuration.
     20feb87
=
     20feb87
=       main loop routines
     20feb87
=
     20feb87
=       dtime      selects time step for next cycle
     20feb87
=       hydro      calculates hydro variable values throughout
     20feb87
=                  active mesh for the current cycle.
     20feb87
```

```
=         lb1        defines left boundary values for method 2
      20feb87
=         lb3        defines left bdry fluxes for eulerian method 2
      20feb87
=        *burn       advances detonation front, converts h.e.
      20feb87
=                    materials and adds chemical energy released by
      20feb87
=                    burning to the burning cell. (burn)
      20feb87
=        *radlos/fbloss1   energy loss by radiation.  routine
      20feb87
=                    included depends on sail option value. (rad)
      20feb87
=        *rezone     redefines mesh coordinates. (rezone)
      20feb87
=        *stuff      redistributes hydro quantities in the
      20feb87
=                    mesh set up by subroutine rezone. (rezone)
      20feb87
=
      20feb87
=        utility routines
      20feb87
=
      20feb87
=        *decide     selects material content of a cell according to
     20feb87
=                    the cell-s position wrt the boundary array. (nm
gt1)  20feb87
=        *const      selects detonation energy and initial velocity
      20feb87
=                    of detonation for h.e. materials. (burn)
      20feb87
=        *eos        calls the appropriate equation of state
      20feb87
=                    routine for the cell in question. (nm gt 1)
      20feb87
=       *visc2     determines the magnitude of the linear viscosity
    20feb87
=                     coefficient as a function of maximum density.
(visc2) 20feb87
=       *q          determines the artificial viscosity to be added
to    20feb87
=                    pressure term in the hydro. (visc lt2)
      20feb87
=        *acmsub      modifies the mass, momentum and total energy
terms    20feb87
=                    in regions of compression to preserve
      20feb87
=                    discontinuities.  (acm)
      20feb87
```

```
=      kill      stops the program on a model condition for a
    20feb87
=                small number of recognized foul ups in the
    20feb87
=                other routines.
    20feb87
=      *rated    thermal heating routine. returns ground
    20feb87
=                level temperatures as a function of incident
    20feb87
=                thermal flux for a given time.(rad4)
    20feb87
=      *dairt    the derivative of subroutine airt. returns
    20feb87
=                the derivative of temperature wrt energy.
    20feb87
=                used in thermal heating calculations.(rad4)
    20feb87
=
    20feb87
=      output routines - most called at std times
    20feb87
=
    20feb87
=      edit      writes to file output.
    20feb87
=      *wtape4   hydro tape4 output (hydra)
    20feb87
=      setz      updates the zblk array.
    20feb87
=      *draw     plots of velocity, overdensity and overpressure
    20feb87
=                vs radius are produced. (plotit)
    20feb87
=      *wtape9   station tape9 output (called from subroutine
    20feb87
=                hydro when a station is encountered) (nstat)
    20feb87
=
    20feb87
=
    20feb87
=
    20feb87
```

Appendix C

```
sap prob=111.0  t=1.e-4
 cycle=0.0   input  cstop=2100  detcel=1.0  rdw=11.0
 angle=0.0  head
  sap run pentolite 100 cells 29 july 92
  hob=0.0 x0=0.0
 region
   bpent=1  speed=.01  dx=11.0  bound=1 cells
   speed=.01 pent=2  dx=10.  bound=3  cells
   pent=2 dx=10.0 bound=75   cells
  air=3  dx=30.  bound=77  cells
  air=3 dx=42. cells
 end
```

```
      subroutine in
      20feb87
c
      20feb87
c*****************************************************************
******* 20feb87
c*
    * 20feb87
c*      this subroutine reads the card input to sap and places the
  * 20feb87
c* values in the proper parameters.
    * 20feb87
c*
    * 20feb87
c*****************************************************************
******* 20feb87
c
      20feb87
$     parameter        (nmat = _nmat_ )
      11feb87
      equivalence      (what, iws)
      20feb87
=
      20feb87
=        input to sap is divided into several sections separated
      20feb87
=     by keywords given below.  all input is in free format.
      20feb87
=
      20feb87
=        the first keyword is "sap" and must in all cases be the
      20feb87
=     first word of data.  three parameters follow
      20feb87
=        t = (time for start of this run.  if not present, default
     20feb87
=        is to a large value, indicating a restart at the end of
      20feb87
=       the last run.  the time may not be .le. zero.  if input as
    20feb87
=        such the program will stop)
      20feb87
=        prob = (problem number)
      20feb87
=        cycle = (cycle number for start of this run.  for a new
      20feb87
=              problem,  cycle=0.0.   default  is  to  a  large
```

value,indicating 20feb87
= a restart at the end of the last run. any other positive
20feb87
= number will result in a restart at that cycle number)
20feb87
= for a new problem, time and cycle must both be specified.
20feb87
= for a restart neither need be input. failure to specify
20feb87
= the correct problem number on a restart will cause sap to
20feb87
= abort.
20feb87
=
20feb87
= for the previous two sections, the data input may appear
more 20feb87
= than once. the latest value will be the one used by the
program. 20feb87
= this is convenient when running two or more problems which
differ 20feb87
= only in the values of the input parameters. input cards may
be 20feb87
= reordered, rather than redone.
20feb87
=
20feb87
= the next section is delimited from the first by the word
20feb87
= "input". data contained in this section pertain to zblock
20feb87
= parameter values, header card information, and the station
20feb87
= coordinates if applicable. with the exception of the header
20feb87
= card, any values in this section may be defaulted to
internally 20feb87
= set values listed below. data in this section may appear in
20feb87
= any order with two exceptions. the header card must be
20feb87
= on a separate card, preceded by the word "head", and the
20feb87
= station coordinates or data for generation of stations must
20feb87
= be preceded by the word "stations" (see below).
20feb87
=
20feb87
= word default definition
20feb87
=

```
        20feb87
=       angle  0.0      angle of run (degrees) +90 degrees - straight
up      20feb87
=       cstop  1.e17    cycle stop
        20feb87
=       c0     1.80     quadratic artificial viscosity coefficient
        20feb87
=       c1     .5       linear artificial viscosity coefficient
        20feb87
=       detcel 0.       number of cell containing detonation wave
        20feb87
=                          this cell separates burned from unburned
regions.   20feb87
=       dstop  1.e9     distance of max pressure stop (cm)
        20feb87
=       dt     1.e-9    time increment (input value used only for
        20feb87
=                       first cycle)
        20feb87
=       dxmul  1.0      increment ratio in exterior cell size (used
        20feb87
=                       in rezone)
        20feb87
=       hob    0.0      height of burst (cm)
        20feb87
=       lbref  1        left boundary reflective indicator
        20feb87
=                       ( a value of 0 - indicating transmissive
        20feb87
=                       left bdry - is sensible only with method 2
        20feb87
=                      and cartesian geometry.  it must be used if a
      20feb87
=                       left boundary input condition is used.)
        20feb87
=      prdw   0.0     radius of detonation wave last cycle (=0.0 for
     20feb87
=                       new problem - set by tape4 read on restart)
        20feb87
=       ptstop 100.     problem time stop (sec)
        20feb87
=       qmin   .1       minimum artificial viscosity (noise level)
        20feb87
=       rdw    0.0      radius detonation wave this cycle (=0.0 for
        20feb87
=                          for a problem with no burn - isothermal
sphere)    20feb87
=       stabf  0.8      stability factor (safety factor in courant
        20feb87
=                       condition time step)
        20feb87
=       umin   1.e-4    minimum hydro velocity (noise limit)
```

```
      20feb87
=      x0      0.0      distance of mesh left edge from origin.  a
non-zero 20feb87
=                      value makes sense only if geom=1. (cm)
      20feb87
=     yield  0.0     yield of device in kt
      20feb87
=     hfb    hob     height of fireball above ground (cm) - (rad4)
     20feb87
=      grndr   0.0      distance from mesh to ground zero (cm) -
(rad4)     20feb87
=
      20feb87
=      any of the above may be rstzbk by specifying the keyword
given     20feb87
=     followed by the desired value.  any such changes must appear
     20feb87
=      in the section labeled "input".
      20feb87
=      some notes on the keywords -cstop-, -dstop-, and -pstop-, if
    20feb87
=      any of the above are found, then the ones found will be the
     20feb87
=      only conditions which will stop sap during a run.  if the
      20feb87
=        user omits all of the stop conditions, then all three
default     20feb87
=      values will be used for ending sap.
      20feb87
=
      20feb87
=          the sputin section should follow the input section, and
    20feb87
=       it can be before or after the header card sequence.  the
default  20feb87
=      values found here are different once the key word -sputin-
is     20feb87
=      encountered.  following the afore mentioned keyword are the
     20feb87
=      following parameters
      20feb87
=
      20feb87
=      word  default      definition
      20feb87
=
      20feb87
=      yield 0.0     yield of device in kt.
      20feb87
=      scale n/a     if this word is encountered, then the data is
     20feb87
=                      scaled to user input - i.e. yield and hob.
```

```
      20feb87
=      hob   0.0     height of burst in cm.
      20feb87
=      fb    none     mandatory name of sputter tape to be used.
the     20feb87
=                    actual tape itself should be called tape3 in
the    20feb87
=                    users local file space.
      20feb87
=      dx    100.     cell width after the sputter tape input has
been    20feb87
=                    put into the mesh.
      20feb87
=
      20feb87
=      note that the parameters yield, hob, and dx are found in
other    20feb87
=      input sections, these values must appear in the -sputin-
      20feb87
=      section or the values are not guaranteed to be of value.
      20feb87
=      it is also important to note that the -region-
      20feb87
=     section is ignored when sputter tapes are used as input.  if
the   20feb87
=        angle in the input section is > 0 and if the -scale-
parameter is 20feb87
=      set, then  it will scale the data to a mesh cut at that
angle.    20feb87
=
      20feb87
=      stations may be specified if desired in one of two ways
      20feb87
=
      20feb87
=         stations  explicit (nstat values listed in increasing
      20feb87
=         order, to be used as coordinates of stations)
      20feb87
=             - or -
      20feb87
=         stations  xs0 = (coordinate of first station)
      20feb87
=                   dx = (distance between adjacent stations)
      20feb87
=      either parameter may be specified first, and both must be
present  20feb87
=     if sail option "nstat" is set to 0, of course no keyword or
      20feb87
=     data pertaining to stations should be present in input.
      20feb87
=
```

```
     20feb87
=      the final section of data is begun with the word "region".
   20feb87
=    this section need not be included for a new problem if option
   20feb87
=     "sputin" is set.
     20feb87
=     this section is used to set up and stuff the mesh.
     20feb87
=    data in this section consists of groups of 6 values separated
   20feb87
=     by the word "cells".  those values whose defaults suffice
     20feb87
=     need not be input.
     20feb87
=
     20feb87
=        input word   definition
     20feb87
=
     20feb87
=     (material name) (material code)  material name abbreviation
     20feb87
=                         specifies what material is in this part of
     20feb87
=                        the mesh.  acceptable names are air,tnt,btnt,
   20feb87
=                                pent,bpent,meth,bmeth,pbx,bpbx,anfo
banfo,water.   20feb87
=                         code must agree with the code assigned the
     20feb87
=                         material in the sail option list
     20feb87
=                         (default is air=1)
     20feb87
=
     20feb87
=     dx                  width of cells in this part of the mesh
     20feb87
=                         default is dx=0.0
     20feb87
=
     20feb87
=     energy              energy density to be inserted in cells in
     20feb87
=                         this part of the mesh (erg/gm).  default
     20feb87
=                         is ambient energy of the material.
     20feb87
=
     20feb87
=     rho                 mass density of cells in this part of mesh
```

```
     20feb87
=                         (gm/cm**3).  default is ambient density.
     20feb87
=
     20feb87
=    speed                 speed of material in this part of the mesh.
     20feb87
=                         at least the first cell must be assigned some
   20feb87
=                          small initial velocity (if less than umin,
this    20feb87
=                         initial velocity will not be present by cycle
1).  20feb87
=                         if there is a zero velocity in the first cell
the  20feb87
=                          program will stop.
     20feb87
=                          default is 0.0 cm/sec.
     20feb87
=
     20feb87
=    bound                 maximum cell number for which the previous
     20feb87
=                          five values hold (default - bound=imax)
     20feb87
=
     20feb87
=
     20feb87
=    these six words may appear in any order within a group.
     20feb87
=    they must be followed by the word "cells".  groups must be
     20feb87
=    given in order of increasing distance from the center of the
    20feb87
=    problem.  of course groups may not be mixed.
     20feb87
=
     20feb87
=       the final word of data input on cards must be the
     20feb87
=    word "end".
     20feb87
=
     20feb87
=
     20feb87
=
     20feb87
=       as an example,  a data set for a new problem consisting
     20feb87
=    of 100 cells, 75 pentolite (the first cell must be burned)
```

```
      20feb87
=     and the remaining 25 cells air at ambient conditions follows.
    20feb87
=      fifty stations at intervals of 25. cm are generated.  the
      20feb87
=     material codes are presumed to be identical with those input
as    20feb87
=     sail options.  imax and nstat=no  of stations are also set by
    20feb87
=      sail options.
      20feb87
=
      20feb87
=      sap   prob=2001.00    t=1.e-4
      20feb87
=        cycle=0.0     input  cstop=2100.  detcel=1.0  rdw=11.0
      20feb87
=       angle=0.0   head
      20feb87
=                     sap run pentolite 100 cells   4 apr 75
      20feb87
=      hob=0.0   stations  dx=25.  xs0=0.0
      20feb87
=      region
      20feb87
=            bpent=2  speed=.01  dx=11.0  bound=1  cells
      20feb87
=  speed=.01  pent=3  dx=10.  bound=3  cells
      20feb87
=  pent=3  bound=75  dx=10.0  cells
      20feb87
=  air=1  dx=30.  bound=77   cells
      20feb87
=  air=1  dx=42.  cells
      20feb87
=                                  end
      20feb87
=
      20feb87
=
      20feb87
=
      20feb87
=         deletion of the statement cycle=0.0 and an increment of
      20feb87
=     the previous run-s stop limit (cstop, dstop, or ptstop) with
     20feb87
=      the rest of the data unchanged will result in a restart
      20feb87
=      beginning where the last run stopped.  any changes in input
      20feb87
=      will take precedence over tape4 values obtained from the
```

20feb87
= the zblock, except of course those parameters which change
20feb87
= with time (eg - detcel,rdw,shkcel). if restarting before a
20feb87
= rezone has occurred, the inactive portion of the mesh
20feb87
= (cells shkcel+2 to imax) will be restuffed with the
20feb87
= appropriate data from the "region" section. if a remesh has
20feb87
= taken place in the previous run, the inactive cells are
20feb87
= initialized at ambient air conditions with a width equal to
20feb87
= the last undisturbed cell in the mesh
(x(shkcel+1)-x(shkcel)). 20feb87
= in this case, the "region" data is ignored and may be deleted
20feb87
= (omit the keyword as well). in all cases "end" must mark the
20feb87
= end of the sap card data.
20feb87
=
20feb87
=
20feb87
= an example of a problem using sputter data as input is
the 20feb87
= following.
20feb87
=
20feb87
=
20feb87
= sap t=1.e-3 prob=1313.00 cycle=0.00
20feb87
= input angle=0.0
20feb87
= head
20feb87
= sputter input example$
20feb87
= sputin yield=2.0 hob=5.e5 scale fb=fb21 dx=.2
20feb87
= end
20feb87
=
20feb87
= where the sputter tape fb21 is used with data from a dump
closest 20feb87
= to but latter than 1.e-3sec. this data will be scaled to a

```
2 kt  20feb87
=       burst at 5 km.  the remaining cells will be .2 cm filled
with      20feb87
=       ambient air conditions.  note that the '$' on the header
card      20feb87
=      is for disspla plotting routines and must be present
      20feb87
=      as a string terminator.
      20feb87
=
      20feb87
```

Appendix E

```
#
#    Batch File jobsap.com
#
#              embedded NQS options
# @$-eo  # directs stderr to stdout
# @$-lt 0:30:00  # per-process CPU time
# @$-lT 0:30:00  # per-request CPU time
# @$     # end of embedded NQS options
#
#    Add SAP to the HULL Library
#
cd /u2/h5serag0/sap
#
ln /u2/h5serba0/HULL122/hull122.system old
#
cat >sail.in <<EOF
sail version 122.1 update
*i 189999
*b  runsap
*keepto runsap runsap eq1
*read modif.cr
*label runsap
EOF
sail <sail.in >sail.s.out
ln new sapv1.system
rm -f new old
#
#    Re-Sequence HULL Library
#
ln sapv1.system old
#
cat >sail.in <<EOF
sail version 123 update
seq program runsap
EOF
sail <sail.in >sail.s.out
ln new sapv2.system
rm -f new old
#
#    This converts the program runsap from the hull binary
#    to ascii format
#                         (Stored in sapv1.system)
#
ln sapv2.system old
#
cat >sail.in <<EOF
sail copy convert
EOF
```

```
sail <sail.in >sail.s.out
ln new runsap.ascii
rm -f new old
#
#    This prepares coded hull library of runsap
#    from runsap.ascii

#
ln runsap.ascii old
#
cat >sail.in <<EOF
sail convert copy
EOF
sail <sail.in >sail.s.out
ln new sapv3.system
rm -f old new
#
#    Now Compile and Run SAP
#
ln sapv3.system old
#
cat >sail.in <<EOF
sail lineno options runsap=1 endoptions program sap
EOF
sail <sail.in >sail.s.out
mv source sap.f
#
#
cat >segldr.in <<EOF
preset=-indef
abs=sap
bin=sap.o
EOF
#
cft77 -a static -l sap.l sap.f
segldr segldr.in
#
time sap <sap.in >sap.out
#
```

Appendix F

```
1        sap run        pentolite        100 cells        29 july 92

                                          z        block

          prob                         1.1100E+02
bdry                       1.0000E+00
          airopt                       1.0000E+00
bdry                       7.5000E+01
          angle                        0.0000E+00
bdry                       1.0000E+02
          atmos                      2.0000E+00
                    0.0000E+00
          bsum                       0.0000E+00
                    0.0000E+00
          burnout                    0.0000E+00
                    0.0000E+00
          cstop                      2.1000E+03
                    0.0000E+00
          c0                         1.8000E+00
                    0.0000E+00
          c1                         5.0000E-01
                    0.0000E+00
          cycle                      0.0000E+00
                    0.0000E+00
          detcel                     0.0000E+00
                    0.0000E+00
          dstop                      1.0000E+09
                    0.0000E+00
          dt                         1.0000E-09
                    0.0000E+00
          dtmin                      1.0000E+20
                    0.0000E+00
          dxmul                      1.0000E+00
                    0.0000E+00
          eth                        8.3418E+16
                    0.0000E+00
          euler                      0.0000E+00
                    0.0000E+00
          geom                       3.0000E+00
                    0.0000E+00
          grndr                      0.0000E+00
                    0.0000E+00
          hfb                        0.0000E+00
                    0.0000E+00
          hob                        0.0000E+00
```

0.0000E+00
imax 1.0000E+02
0.0000E+00
lbref 1.0000E+00
0.0000E+00
method 1.0000E+00
0.0000E+00
nh 5.0000E+00
0.0000E+00
nstat 0.0000E+00
0.0000E+00
nvarpr 2.5000E+01
0.0000E+00
nzblk 4.2000E+01
0.0000E+00
prdw 0.0000E+00
0.0000E+00
ptstop 1.0000E+02
0.0000E+00
qmin 1.0000E-01
0.0000E+00
rad 0.0000E+00
0.0000E+00
radsum 0.0000E+00
0.0000E+00
rdw 1.1000E+01
0.0000E+00
rezone 1.0000E+00
0.0000E+00
shkcel 4.0000E+00
0.0000E+00
stabf 8.0000E-01
0.0000E+00
t 1.0000E-04
0.0000E+00
thm 7.0947E+08
0.0000E+00
umin 1.0000E-04
0.0000E+00
visc 1.0000E+00
0.0000E+00
yield 0.0000E+00
0.0000E+00
nmat 3.0000E+00
0.0000E+00
bpent 1.0000E+00
0.0000E+00
pent 2.0000E+00
0.0000E+00
air 3.0000E+00
0.0000E+00

1 sap run pentolite 100 cells 29 july 92

```
                                   z      block

                      bpent                   1              1
1.1000E+01
                      pent                    2             75
7.5100E+02
                      air                     3            100
1.7770E+03
1  sap run         pentolite       100 cells       29 july 92


     problem   111.00000    cycle =     0.     t =  1.00000E-04
total energy eth =  8.34180E+16     total mass thm =  7.09472E+08

     mesh values start of this run

   j          x             u              p              epg
 rho            temp            zm             dx             j
   1     1.10000E+01    1.00000E-02    1.03766E+11    5.15500E+10
1.66000E+00    0.00000E+00    2.20946E+03    1.10000E+01       1
   2     2.10000E+01    1.00000E-02    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    1.31638E+04    1.00000E+01       2
   3     3.10000E+01    1.00000E-02    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    3.40798E+04    1.00000E+01       3
   4     4.10000E+01    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    6.49558E+04    1.00000E+01       4
   5     5.10000E+01    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    1.05792E+05    1.00000E+01       5
   6     6.10000E+01    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    1.56588E+05    1.00000E+01       6
   7     7.10000E+01    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    2.17344E+05    1.00000E+01       7
   8     8.10000E+01    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    2.88060E+05    1.00000E+01       8
   9     9.10000E+01    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    3.68736E+05    1.00000E+01       9
  10     1.01000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    4.59372E+05    1.00000E+01      10
  11     1.11000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    5.59968E+05    1.00000E+01      11
  12     1.21000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    6.70524E+05    1.00000E+01      12
  13     1.31000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    7.91040E+05    1.00000E+01      13
  14     1.41000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    9.21516E+05    1.00000E+01      14
  15     1.51000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00    0.00000E+00    1.06195E+06    1.00000E+01      15
  16     1.61000E+02    0.00000E+00    1.01325E+06    1.00000E+08
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1.66000E+00   0.00000E+00   1.21235E+06   1.00000E+01   16
  17   1.71000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   1.37270E+06   1.00000E+01   17
  18   1.81000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   1.54302E+06   1.00000E+01   18
  19   1.91000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   1.72330E+06   1.00000E+01   19
  20   2.01000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   1.91353E+06   1.00000E+01   20
  21   2.11000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   2.11373E+06   1.00000E+01   21
  22   2.21000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   2.32388E+06   1.00000E+01   22
  23   2.31000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   2.54400E+06   1.00000E+01   23
  24   2.41000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   2.77408E+06   1.00000E+01   24
  25   2.51000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   3.01411E+06   1.00000E+01   25
  26   2.61000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   3.26411E+06   1.00000E+01   26
  27   2.71000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   3.52406E+06   1.00000E+01   27
  28   2.81000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   3.79398E+06   1.00000E+01   28
  29   2.91000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   4.07386E+06   1.00000E+01   29
  30   3.01000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   4.36369E+06   1.00000E+01   30
  31   3.11000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   4.66349E+06   1.00000E+01   31
  32   3.21000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   4.97324E+06   1.00000E+01   32
  33   3.31000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   5.29296E+06   1.00000E+01   33
  34   3.41000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   5.62264E+06   1.00000E+01   34
  35   3.51000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   5.96227E+06   1.00000E+01   35
  36   3.61000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   6.31187E+06   1.00000E+01   36
  37   3.71000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   6.67142E+06   1.00000E+01   37
  38   3.81000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   7.04094E+06   1.00000E+01   38
  39   3.91000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   7.42042E+06   1.00000E+01   39
  40   4.01000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   7.80985E+06   1.00000E+01   40
  41   4.11000E+02   0.00000E+00   1.01325E+06   1.00000E+08
1.66000E+00   0.00000E+00   8.20925E+06   1.00000E+01   41
  42   4.21000E+02   0.00000E+00   1.01325E+06   1.00000E+08
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1.66000E+00   0.00000E+00   8.61860E+06   1.00000E+01     42
  43     4.31000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   9.03792E+06   1.00000E+01     43
  44     4.41000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   9.46720E+06   1.00000E+01     44
  45     4.51000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   9.90643E+06   1.00000E+01     45
  46     4.61000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.03556E+07   1.00000E+01     46
  47     4.71000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.08148E+07   1.00000E+01     47
  48     4.81000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.12839E+07   1.00000E+01     48
  49     4.91000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.17630E+07   1.00000E+01     49
  50     5.01000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.22520E+07   1.00000E+01     50
1  sap run       pentolite       100 cells        29 july 92


    problem   111.00000    cycle =     0.     t =  1.00000E-04
total energy eth =  8.34180E+16     total mass thm =  7.09472E+08

    mesh values start of this run

   j           x              u               p              epg
 rho             temp            zm             dx              j
  51     5.11000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.27510E+07   1.00000E+01     51
  52     5.21000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.32600E+07   1.00000E+01     52
  53     5.31000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.37789E+07   1.00000E+01     53
  54     5.41000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.43078E+07   1.00000E+01     54
  55     5.51000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.48466E+07   1.00000E+01     55
  56     5.61000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.53954E+07   1.00000E+01     56
  57     5.71000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.59541E+07   1.00000E+01     57
  58     5.81000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.65229E+07   1.00000E+01     58
  59     5.91000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.71015E+07   1.00000E+01     59
  60     6.01000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.76902E+07   1.00000E+01     60
  61     6.11000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.82888E+07   1.00000E+01     61
  62     6.21000E+02    0.00000E+00    1.01325E+06    1.00000E+08
1.66000E+00   0.00000E+00   1.88973E+07   1.00000E+01     62
  63     6.31000E+02    0.00000E+00    1.01325E+06    1.00000E+08
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1.66000E+00	0.00000E+00	1.95158E+07	1.00000E+01	63
64	6.41000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.01443E+07	1.00000E+01	64
65	6.51000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.07828E+07	1.00000E+01	65
66	6.61000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.14311E+07	1.00000E+01	66
67	6.71000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.20895E+07	1.00000E+01	67
68	6.81000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.27578E+07	1.00000E+01	68
69	6.91000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.34361E+07	1.00000E+01	69
70	7.01000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.41243E+07	1.00000E+01	70
71	7.11000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.48225E+07	1.00000E+01	71
72	7.21000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.55307E+07	1.00000E+01	72
73	7.31000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.62488E+07	1.00000E+01	73
74	7.41000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.69769E+07	1.00000E+01	74
75	7.51000E+02	0.00000E+00	1.01325E+06	1.00000E+08
1.66000E+00	0.00000E+00	2.77149E+07	1.00000E+01	75
76	7.81000E+02	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	6.46981E+04	3.00000E+01	76
77	8.11000E+02	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	6.98644E+04	3.00000E+01	77
78	8.53000E+02	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	1.06867E+05	4.20000E+01	78
79	8.95000E+02	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	1.17927E+05	4.20000E+01	79
80	9.37000E+02	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	1.29531E+05	4.20000E+01	80
81	9.79000E+02	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	1.41680E+05	4.20000E+01	81
82	1.02100E+03	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	1.54373E+05	4.20000E+01	82
83	1.06300E+03	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	1.67610E+05	4.20000E+01	83
84	1.10500E+03	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	1.81393E+05	4.20000E+01	84
85	1.14700E+03	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	1.95719E+05	4.20000E+01	85
86	1.18900E+03	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	2.10591E+05	4.20000E+01	86
87	1.23100E+03	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	2.26007E+05	4.20000E+01	87
88	1.27300E+03	0.00000E+00	1.01325E+06	2.04448E+09
1.22500E-03	2.87938E+02	2.41967E+05	4.20000E+01	88
89	1.31500E+03	0.00000E+00	1.01325E+06	2.04448E+09

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 1.22500E-03   2.87938E+02   2.58472E+05   4.20000E+01     89
   90     1.35700E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   2.75521E+05   4.20000E+01     90
   91     1.39900E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   2.93115E+05   4.20000E+01     91
   92     1.44100E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   3.11254E+05   4.20000E+01     92
   93     1.48300E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   3.29937E+05   4.20000E+01     93
   94     1.52500E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   3.49165E+05   4.20000E+01     94
   95     1.56700E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   3.68937E+05   4.20000E+01     95
   96     1.60900E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   3.89254E+05   4.20000E+01     96
   97     1.65100E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   4.10115E+05   4.20000E+01     97
   98     1.69300E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   4.31521E+05   4.20000E+01     98
   99     1.73500E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   4.53472E+05   4.20000E+01     99
  100     1.77700E+03   0.00000E+00   1.01325E+06   2.04448E+09
 1.22500E-03   2.87938E+02   4.75966E+05   4.20000E+01    100
1trouble in subroutine burn - abort
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11. SUPPLEMENTARY NOTES

Task was performed under a Scientific Services Agreement issued by Battelle, Research Triangle Park Office, 200 Park Drive, P.O. Box 12297, RTP, NC 227709

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Spherical Air Puff (SAP) hydrocode was added to the HULL system at the U.S. Army Engineer Waterways Experiment Station (WES) to enhance the capabilities of hydrodynamic calculations. The program is intended to achieve faster execution time and better accuracy in certain hydrodynamic problems. SAP will furnish starting values in HULL hydrodynamic calculations, as well as being an independent capability. The enhanced capability must be tested with different physical problems.

14. SUBJECT TERMS

Air blast, HULL, Hydrodynamic calculations, SAP, Spherical

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